Creating a Paleoclimate Record

Objectives:

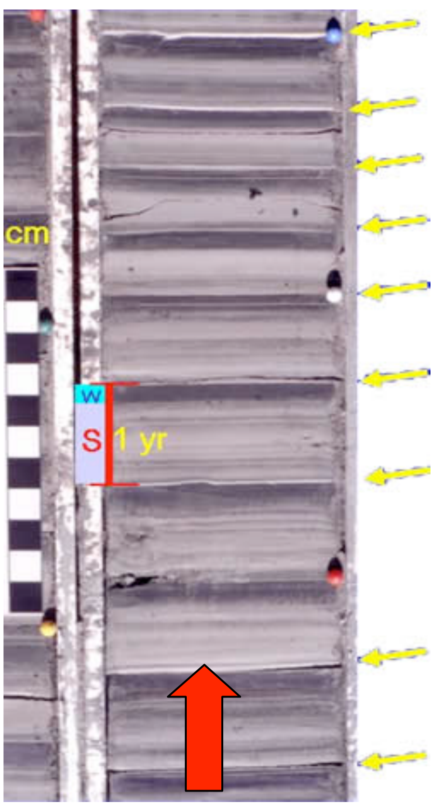
1. To explore the use of climate proxies and investigate how they can be used to study the advance and retreat of glaciers.
2. To understand sediment deposition and how it relates to weather and climate patterns.
3. To reconstruct lake sediment deposition as a climate proxy.

Background:

Climate Proxy

A climate proxy is a preserved record of past geologic or biological processes that were controlled by climate and thus can be used to infer past climate and climate changes. Examples of climate proxies include annual lake sediment layers (varves), stable isotopes of oxygen in shells of marine organisms, thickness of annual ice layers, and annual tree rings. All of these proxies can be used to reconstruct climate patterns in the recent and ancient past.

Understanding a Lake Sediment Varve



A lake varve is defined as an annual sediment layer that is a couplet composed of a light colored "summer" layer and a darker "winter" layer. An example of a lake varve record can be found to the left. A yellow arrow indicates the beginning of a varve year. Note that the varve thicknesses are variable and that a varve year is composed of a light summer layer and its overlying darker winter layer (Note the 1 yr area on the figure to the left). This thickness variability allows varves to be used as a climate proxy. The varves (left) are from a sediment core from the Connecticut River Valley region in Vermont and represent 10 years. These varves are typical of the New England area, but varves from other areas of the world may look different. The varves in this picture were deposited 300 years after the glacial ice retreated from the region approximately 15,000 years ago. The "summer" layer (light color) refers to the period of time in which a lake is not frozen and water running into the lake creates strong bottom currents. "Winter" layers (dark color bands) typically form when the lake is covered by ice and tend to show less variability due to the fact that sediment is not transported into the lake when it is frozen. Instead, fine grains of clay produced during the summer period gradually settle out. As you can see there are thin dark lines interspersed throughout the summer layer. These light intra-summer layers are due to pulses of water from glacial melting, sometimes representing diurnal cycles, rain storm events, or days with warm air and lots of sunlight that cause high melting rates and large influxes of meltwater to the lake.

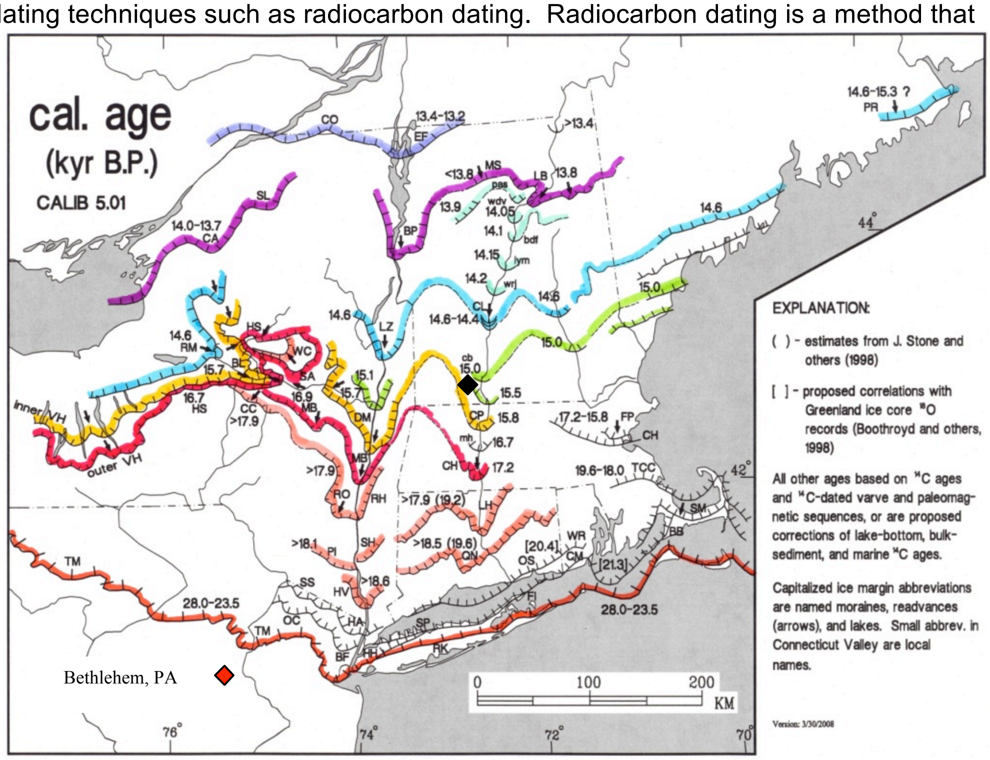
Sometimes a distinct graded bed of sand and silt can be observed in the varve record (red arrow in figure above). This is an indication of a pulse of meltwater from the glacier caused by either rapid snow melt or the sudden opening of sub-glacial tunnels. This is sometimes capped by a thin silty clay bed. It is frequently the coarsest sediment deposited as part of the summer layer.

Changes in varve thickness are associated with changes in meltwater output and sediment deposition, which varies with difference in weather. For example a **warmer year** will have a **thicker varve layer** resulting from more meltwater carrying sediment from the glacier. A **colder year** will have a **thinner varve layer**. In most glacial varve environments, the summer season is shorter than the winter season. However, in some locations, summer sediments may vary greatly (such as in the figure above) depending on bedrock source and erosion rates.

In the class investigation, varves come from a sediment core are taken in an ancient glacial lake, that is initially proximal (close) to the margin of a glacier and over time gradually becomes distal (far away).

<u>Varves as Records of Deglaciation</u>

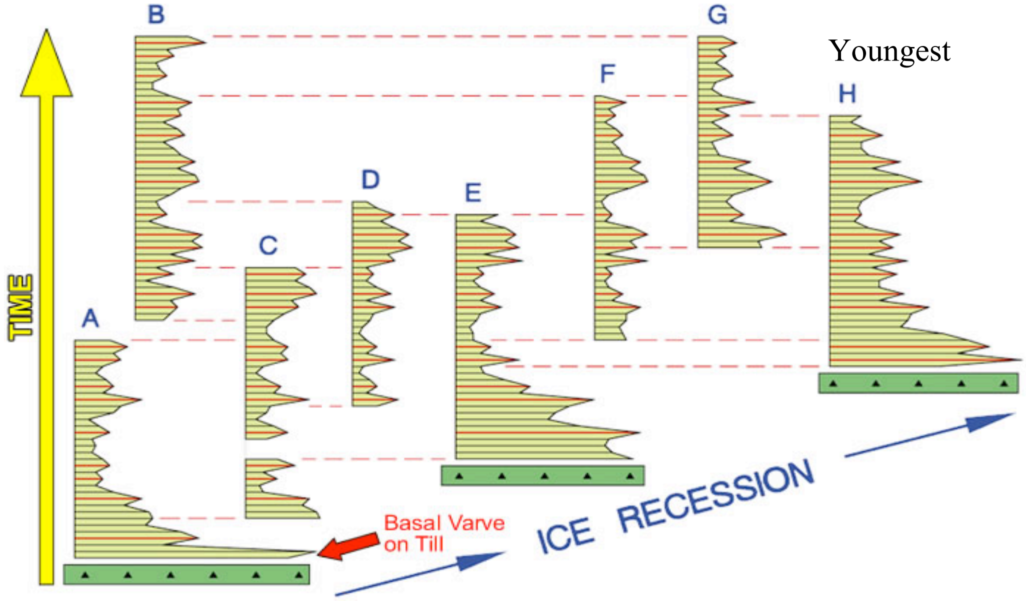
Varve chronology (using varves to set up a time scale) is a useful tool in deciphering the history of ice retreat or deglaciation. Varves are capable of recording various deglaciation events in varve years, which can then be calibrated using absolute dating techniques such as radiocarbon dating. Radiocarbon dating is a method that utilizes the decay of the naturally occurring carbon-14 isotope. It is useful in dating organic material that is less than 40,000 years old.



A deglaciation event refers to the glacial ice retreating and it can be viewed in the Northeastern United States in the picture above. The colored lines mark different landforms that were left by the glacier as it retreated. These are most commonly known as terminal or recessional moraines. The numbers associated with each line refer to the number of years before present (in thousands of years) that the glacier paused to develop that specific landform. As can be seen by the picture, the margin of the glacier reached its furthest extent about ~28 thousand years ago (red line) and then retreated northwards. Lakes that contain varves can be referred to as distal (far away) or proximal (near) to the ice front. The black diamond indicates the location of the core used for the class investigation. The red diamond indicates the location of Bethlehem, PA.

The Basics of Coring

Detailed surficial mapping of ancient glacial lakes can be used to find lake varve exposures. Once a varve outcrop is located it can be cored and measured to produce a varve record. Varve records can be correlated and assembled into a regional composite chronology to understand the spatial pattern of climate change as seen in the figure above. Note the age of the basal varve gets younger in the direction of the ice retreat.



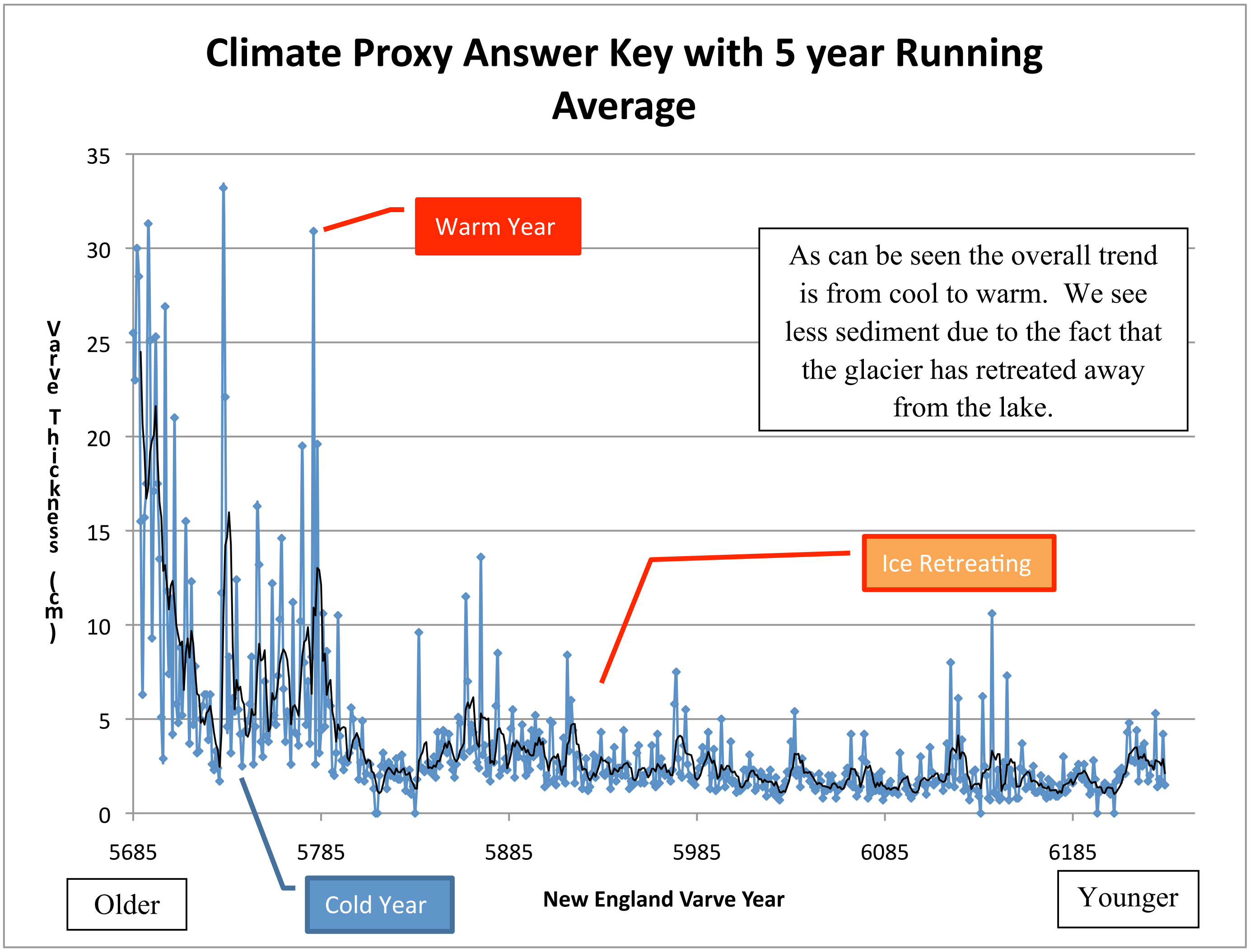
In 1882, geologists began to use varve chronology in Sweden. In 1920 measurements of varve thicknesses in the field were used in America. This method is still used today; however it is recommended that varves are measured in a lab from outcrop cores. Cores allow for more careful measurement and provide samples for doing other things with the sediment such as studying microfossils.

In many places surface varve exposures of sufficient depth to assemble varve sequences cannot be found. In these areas deep drilling may be employed to recover cores of varve sections. A hollow stem auger continuous sampling system can allow the recovery of samples from 5-ft core drives. The sampling system is usually limited to a depth of 120-200 feet depending on the resistance of the material to the auger and the torque limitations of the drilling truck. Taking small overlapping cores (2 feet) is the ideal way to sample a varve section. Once back in lab, the cores can be digitally imaged and then analyzed for inter-annual varve thickness.

The core for this activity was taken along Canoe Brook in Dummerston, VT and represents a period of time about 14,900-14,600 years ago. These varves formed in glacial Lake Hitchcock in southern Vermont which was somewhat proximal to the retreating glacier. The lake was named for Edward Hitchcock who was a geologist from Amherst College that studied the lake. As can be seen from the key below, the climate is colder at the beginning of the varve record and becomes warmer as time moves closer to the present. This is apparent due to the fact that the glacier was proximal to the lake at the beginning of the record and retreated away from the lake as time moved towards the present. As the source of sediment retreats (glacier) the amount being deposited each year decreases.

In the student investigation, the data set is divided into 10 core segments, each composed of about 30 varve layers. The first core is split into an “A” and “B” core, but should still be plotted on the Core 1 graph. The original data set is scaled down by a factor of 10 to ensure that cores fit onto a single 8” x 11” page. Varve measurements should be taken in tenths of centimeters (millimeters) starting at the bottom of each core and working upwards. Measurements less than 1 millimeter are recorded in the data table as 1mm and should be plotted along with the data. Five year increments are marked within each core to help the students stay organized. Measurements should be transferred to the data table and then graphed once all of the data has been collected.

Answer Key:



Citation:

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